EWA Expenditures for Protection of the Delta Smelt
Water Year 2002

Introduction

This report provides a detailed account of the environmental conditions encountered during water year 2002, the distribution of delta smelt in 2002, the rationale for expending Environmental Water Account (EWA) assets, and the environmental conditions/benefits following those expenditures. Additionally, this paper provides conclusions and recommendations for EWA use in the future.

Delta Smelt

The delta smelt (*Hypomesus transpacificus*) was federally listed as a threatened species under the Endangered Species Act of 1973, as amended, on March 5, 1993. This osmerid fish species occurs only in Suisun Bay and the Sacramento-San Joaquin Delta, California. Although highly variable, delta smelt fall abundance indicators have exhibited a marked decline over the past 30 years. This decline was due to (1) reductions in outflow related to increased upstream storage and diversion of water from the Sacramento and San Joaquin Rivers and tributaries, (2) entrainment losses to water diversions at the Central Valley Project and State Water Project, through numerous small agricultural diversions throughout the Delta, and to power plants, (3) extreme high outflow years, (4) changes in the abundance and composition of food organisms, (5) toxic substances, including agricultural pesticides and heavy metals, (6) disease, competition, and predation, and (7) loss of genetic integrity through hybridization with wakasagi (*Hypomesus wakasagi*) (U.S. Fish and Wildlife Service, 1993). Nevertheless, the recovery potential of the delta smelt is thought to be fairly high. The survival of the delta smelt is important not only because it exists nowhere else in the world, but because it is an important component of the Delta ecosystem.

Environmental Water Account

An essential goal of the CALFED program is to provide increased water supply reliability to water users while at the same time assuring the availability of sufficient water to meet fish protection and restoration/recovery needs. As a means to achieving this, the CALFED Agencies developed the Environmental Water Account (EWA). The EWA focuses on resolving the fish/water diversion conflict at the Central Valley Project (CVP) and State Water Project (SWP) Delta export facilities by adopting an adaptive management approach to protect the fish of the Bay-Delta estuary through environmentally beneficial changes in CVP/SWP operations, at no uncompensated water cost to the Projects' water users. This approach to fish protection requires the acquisition of alternative sources of project water supply, called "EWA assets."

In providing protection to delta smelt, EWA assets may be used to augment Delta flows (inflows and/or outflows), modify CVP and/or SWP exports, and replace project water interrupted by changes to project operations. Having the ability to modify habitat

conditions in the Delta in real-time, rather than relying solely on prescriptive standards, affords better protection to delta smelt and further allows the species to move towards recovery. It should be noted that expenditures of EWA assets for delta smelt protection is closely tied to the operation, or non-operation, of the south Delta temporary or permanent barriers (Figure 1). Unlike salmonids, there is no evidence to suggest that delta smelt benefit from the barriers.

Tools

Several monitoring methods have been used to obtain information on the various life-stages of delta smelt and its real-time abundance and distribution in the Delta. For adult fish, these tools include (1) Fall Mid-Water Trawl indices, (2) Spring Mid-Water Trawl indices, (3) Beach Seine sampling, (4) Chipps Island Trawl, and (5) fish condition (gravid vs. spent). For larval delta smelt, these methods include (1) Light Trapping surveys and (2) 20-mm surveys. For juvenile fish, these methods include (1) 20-mm surveys and (2) summer townet surveys. Methods common to all life stages include (1) hydrology (wet vs. dry), (2) X2 location, (3) water quality and water temperature, (4) rate of export, and (5) salvage at the export facilities, although this "sampling" method was less effective for larval and early juvenile fish. All life stages of delta smelt are vulnerable to being captured by the CVP and SWP export facilities. During a large portion of their life cycle, delta smelt are either too small or not strong enough to avoid going through the louvers at the export facilities, and when they do, they likely do not survive.

The Delta Fish Facilities Salvage Monitoring Program was the source for daily salvage and loss estimates for the monitoring of incidental take of listed fish species by southern Delta water export facilities. The entire fish facility structure functioned as the collection mechanism, operating whenever water was being exported.

After conducting the various surveys and obtaining the information from the various monitoring tools, the resulting data were integrated into the Delta Smelt Decision Tree (Nobriga 2001, copy attached) to assess the level of concern for delta smelt in relation to their abundance and distribution in the Delta. The Delta Smelt Decision Tree outlined concerns likely to be encountered for each life stage of delta smelt, provided a means by which to assess those concerns in relation to the environmental conditions, and allowed recommendations to be made based upon interpretation of the above factors by the Delta Smelt Work Group. Applying the most current information available to the Decision Tree, the Delta Smelt Work Group made any necessary recommendations to reduce exports and/or modify Delta inflows and outflows, barrier operations, and Delta Cross-Channel Gate operation.

Environmental Conditions/Smelt Situation in 2002

The export facilities began reporting WY 2002 delta smelt take in December of 2001. The monthly salvage for water year 2002 is summarized in Table 1. A summary of EWA expenditures for water years 2001 and 2002 is presented in Table 2.

JANUARY

As the take of adult delta smelt reached 2,106 on January 3, the Delta Smelt Work Group convened on January 4 to discuss salvage levels at the SWP and CVP export facilities. Preliminary examinations of females revealed ova sizes of approximately 0.1 to 0.4 millimeters, indicating that these fish were roughly one month away from spawning. The Work Group concluded that these adult fish should be protected, and that an action should be taken to reduce exports. Based upon the projected rate of take, the "red light" level would likely have been reached by January 9, requiring that alternatives be developed for project exports. As most of the entrainment was occurring at the SWP pumps, the Work Group recommended that the SWP curtail exports from 7,850 to 1,500 cfs from January 5 to January 9. NMFS concurred with the recommendation to reduce exports, for the benefit of spring-run chinook salmon. The daily take of delta smelt dropped from a high of 840 on January 4 to 222 on January 5, and remained at this lower level (80-222) throughout the five-day period. By January 9, total take had reached 3,723. Daily salvage remained below 200 after January 10, for a total January take of 5,231 (Figure 2).

EWA Costs. The Department of Water Resources estimated that SWP exports were reduced by approximately 66,000 acre feet as a result of this action (Fish Action #3-02). Future settlements of EWA costs and credits will reflect the actual cost of water, energy, storage and conveyance incurred.

FEBRUARY

Management agency staff took advantage of an opportunity to relax the Export /Import (E/I) ratio in the Delta in order to acquire EWA assets, as permitted by the State Water Resources Control Board Decision 1641 and the CALFED Record of Decision. The E/I ratio was relaxed from 35% to as much as 45% from February 1 through 16 and February 19 through 26, allowing the EWA to accrue approximately 80,000 acre feet of storage in San Luis Reservoir. The threshold values agreed upon for ending the E/I relaxation were (1) a daily salvage number of 150 non-tagged winter-run-size chinook salmon or (2) a daily salvage number ten times the 14-day running average for delta smelt. Daily salvage of delta smelt at the export pumps remained below 30 over the entire month, for a total monthly take of 280. The San Joaquin River at Vernalis flow standard of 2280 cfs required under the Water Quality Control Plan was not met, as this would have required additional releases from New Melones reservoir. There was concern among Bureau of Reclamation staff that if sufficient water was released to meet the flow standard, not enough would remain to conduct the Vernalis Adaptive Management Plan (VAMP) in April and May. The Delta Smelt Work Group concluded that, with most smelt occurring in Montezuma Slough and the lower San Joaquin River, delta smelt would experience no substantial impacts or take from failure to meet the Vernalis water quality standard.

MARCH

Daily take of delta smelt was low throughout the month, peaking on March 5 and 6 with counts of 36 and 54, respectively, for a total monthly take of 225. The 20 mm survey began on March 18, but did not collect any delta smelt (Figure 3). No EWA actions were taken on behalf of delta smelt in March.

APRIL

The 20 mm survey indicated the presence of delta smelt in the South Delta (Old River north of Clifton Court Forebay) as early as April 2 (Figures 4, 5 and 6), with numbers declining toward the end of the month. Daily smelt take remained low (under 100) throughout April, with a total monthly take of 372. The Vernalis Adaptive Management Plan (VAMP) experiment began on April 15, as combined exports were held at 1500 cfs. The VAMP generally benefitted juvenile San Joaquin fall-run chinook salmon, delta smelt and other resident fishes by improving flows in the south Delta, supporting Delta habitat and decreasing entrainment at the project pumps. EWA expenditures for the period from April 15 through May 15 exceeded 45,000 acre feet (approximately 28,000 in April). Installation of temporary barriers began at Head of Old River on April 2, at Old River near Tracy on April 1, at Middle River on April 10, and at Grant Line Canal on April 1. The culverts on the Head of Old River barrier remained open, as modeling indicated that to do otherwise would impact downstream water levels. The barriers at Old River near Tracy and at Middle River operated normally, with flap gates closed. The center portion of the Grant Line Canal barrier remained open, with the culverts tied open. The purpose of construction and operation of the barriers was to increase water levels in the South Delta in support of individual agricultural diversions, as well as to reduce impacts to migrating juvenile salmon at the water project pumps. There is evidence to suggest that delta smelt do not receive benefits from the barriers, as construction of the barriers impacts critical habitat and their operation alters circulation patterns throughout the South Delta and likely increases the take of delta smelt through unscreened agricultural diversions.

EWA Costs. The Department of Water Resources estimated that SWP exports were reduced by approximately 28,000 acre feet during the month of April as a result of this action (Fish Action #6-02). Concurrently, CVP exports were reduced using CVPIA (b)(2) water. Future settlements of EWA costs and credits will reflect the actual cost of water, energy, storage and conveyance incurred.

MAY

By mid-May, the 20 mm survey (surveys 5 and 6; see Figures 7 and 8) indicated that most delta smelt had left the South Delta and were apparently moving toward the confluence, where they were expected to remain throughout the summer. Export reductions at the SWP pumps continued through May 15 in support of the VAMP, totaling approximately 17,000 acre feet. During the period from May 16 through May 31, exports were reduced by approximately 70,000 acre feet at the CVP and 62,000 acre feet at the SWP pumps (the

"VAMP shoulder") to maintain a net positive flow in the Delta and reduce entrainment of juvenile salmon and delta smelt at the export facilities. Removal of the temporary barrier at the Head of Old River began on May 22, and was completed on June 7. On May 22 the gates at the Old River near Tracy barrier were tied open at the request of the management agencies, in an attempt to further reduce take of delta smelt at the export pumps. The Middle River barrier's gates were tied open on May 26. Increased pumping by the SWP for several hours on May 16 and May 25 resulted in an unusually high take of delta smelt for those two days (2556 and 20,742, respectively). This pumping, which did not increase the volume of water taken into Clifton Court Forebay, was part of an experiment conducted by the Department of Water Resources in an attempt to predict the level of delta smelt salvage when export pumping resumed following the VAMP. Delta smelt salvage reached "yellow light" conditions (a 14-day running average of 400 hundred or more at the export facilities, as defined by the Services'1995 Biological Opinion) on May 12; salvage remained in the yellow-light range through the end of May and into June. Total monthly salvage of delta smelt at the export facilities was 47,325 for the month of May (Figure 11).

EWA Costs. The Department of Water Resources estimated that SWP exports were reduced by approximately 79,000 acre feet and CVP exports by approximately 70,000 acre feet during the month of May as a result of these actions (Fish Actions #6-02 and #7-02). Future settlements of EWA costs and credits will reflect the actual cost of water, energy, storage and conveyance incurred.

JUNE

The Delta was in balanced condition, wherein reservoir releases plus unregulated flow equal in-basin needs plus exports, as of June 3. As salvage rates remained high at the end of May, the management agencies requested that export pumping be increased at a moderate rate ("ramped") from June 1 through June 2, to minimize entrainment of delta smelt. Combined daily salvage dropped below 200 after June 10, where with the exception of June 19 and June 20 it remained, resulting in a monthly take of 11,950 (Figure 12). The 20 mm survey (surveys 7 and 8; see Figures 9 and 10) sampled no delta smelt in the South Delta during the month of June; however, the combined 14-day average delta smelt salvage at the export facilities remained within the yellow light range until June 18. The Delta Smelt Work Group was not concerned, however, as it was assumed that smelt salvage consisted of fish resident in Clifton Court Forebay. Normal tidal operations resumed at the Old River near Tracy barrier on June 1 and at the Middle River barrier on June 2. The center portion of the Grant Line Canal barrier was closed on June 14, but the flap gates remained open. Normal operations were authorized beginning June 19; however, crews discovered that the gates had already been lowered in an apparent act of vandalism.

EWA Costs. The Department of Water Resources estimated that SWP exports were reduced by approximately 3,000 acre feet and CVP exports by approximately 2,000 acre feet during the month of June as a result of this action (Fish Action #8-02). Future

settlements of EWA costs and credits will reflect the actual cost of water, energy, storage and conveyance incurred.

Discussion

The Environmental Water Account Team (EWAT) built upon the accomplishments of water year 2001 to successfully implement the purpose of the EWA, creatively employ its assets, and minimize impacts to resident and migratory fish in the Sacramento-San Joaquin Delta from export pumping and incidental take. Real-time expenditure of assets was optimized via close coordination between the Management and Project agencies, with the assistance of the Data Assessment Team (DAT) and the Delta Smelt Work Group.

The primary strategy of delta smelt management is to anticipate prevailing conditions and to coordinate project operations so as to support a healthy Delta environment, wherein delta smelt spawning and rearing conditions are favorable. Delta smelt distribution is highly variable, as is the physical environment (flow, salinity and other factors). It is likely that freshwater inflow and overall Delta hydrology influence the distribution of delta smelt. EWA expenditures supporting export curtailments in January contributed to positive net flows in the Delta, which encouraged pre-spawn adult smelt movement into areas north and west of the export pumps. DFG's 20 millimeter survey began sampling delta smelt in the southern and interior Delta in early April, where spawning and rearing conditions were likely to be marginal and risk of entrainment at the export facilities was substantial. Pulse flows and EWA-supported export reductions made during and following the VAMP period created conditions conducive to downstream movement. By mid-May delta smelt had moved north and west, and by late May their distribution was centered in the western Delta near the confluence of the Sacramento and San Joaquin Rivers. In this location, young-of-the-year could be expected to experience favorable rearing conditions.

Approximately 268,000 acre-feet of EWA assets were used to improve Delta habitat conditions and minimize the entrainment of salmonids and delta smelt at the export pumps in 2002. The overall salvage rates of delta smelt were low, entering the yellow light range for only a 36-day period from mid-May through mid-June. With the exception of May, salvage generally remained well below the red light level (Table 1), which if attained would have required that the Delta Smelt Work Group meet to develop alternative export strategies. While some of the low salvage rate can be attributed to reduced project pumping due to the below-normal year, it is likely that EWA expenditures contributed to improved environmental conditions in the southern Delta, as discussed above.

A. *Accomplishments during EWA implementation in water year 2002:*

1. The Delta Smelt Work Group continued to use a structured process for evaluating data (delta smelt decision tree) and to assess conditions and formulate recommendations for EWA actions to benefit fish in water year 2002. Additional information was also obtained using Particle Tracking Modeling.

2. Staff of the Management and Project agencies and stakeholders communicated, cooperated, and coordinated effectively during water year 2002 to implement the EWA. This process occurred in DAT conference calls, the Delta Smelt Work Group, and in meetings with DWR staff modelers. This professional interdisciplinary team approach was evidence of a solid commitment to the EWA effort.

3. Through close coordination via the DAT conference calls and the Delta Smelt Work Group, the flap-gates on the temporary barriers were operated so as to minimize hydraulic impacts to delta smelt while maintaining water supply to south Delta agriculture interests.

4. An extensive and reliable fish monitoring effort (20 millimeter survey) enabled the Management Agencies to identify relative abundance and distribution of delta smelt at various locations in the Sacramento-San Joaquin Delta area. This information helped staff to anticipate periods of heightened concern for delta smelt in the Delta and at the export facilities, thus allowing staff to make recommendations for planned and real-time export reductions.

5. A vast amount of biological, hydrological, and operational data was collected and made available to the DAT and the Delta Smelt Work Group to support the decision process for use of EWA assets. Without this critical foundation, the cooperation of the Management and Project Agencies, and professional commitment to field crews and data management staff working throughout the Delta, this program could not have been implemented.

6. A comprehensive set of DAT conference call and Delta Smelt Work Group notes were compiled and reviewed in a timely fashion. The notes provided an excellent record of events and decisions made and that record, supplemented by the *Fish Action* documents, served well in recapping the entire EWA process in water year 2002.

7. The EWA was coordinated with management of the CVPIA 3406 (b)(2) water dedicated to fish and wildlife to provide expanded fish benefits and water supply reliability. This included using EWA assets for an export reduction at the CVP facilities during late May and early June.

8. EWA assets were used to support a healthy Delta environment, wherein delta smelt spawning and rearing conditions were favorable, and to minimize incidental take of delta smelt at the CVP and SWP export pumps, in keeping with the 1995 Biological Opinion.

9. The EWA process in water year 2002 was carried out in an open forum so as to focus the awareness of policy makers, managers, and the general public to the challenge of balancing the use of our water resources.

10. A Delta Smelt Workshop was held in September 2002, focusing on research needs. The second EWA annual review workshop will take place in October 2002.

B. *Limitations encountered during EWA implementation in water year 2002:*

1. The way in which Endangered Species Act (ESA) incidental take levels are determined and used is unclear to some participants. A better understanding of this process and the quantitative rationale for targeting specific take levels is needed for the EWA process to be widely supported. It is also important to evaluate potential flexibility in ESA implementation to better enable field and laboratory experimentation to occur.

2. While making decisions to provide benefits to delta smelt in real time, staff often found themselves in a re-active rather than a pro-active mode. To reverse this trend, a series of Particle Tracking modeling using various river flow rates, export rates, and south Delta barrier configurations should be conducted up-front. This would provide a better idea of the steps needed to improve protection for delta smelt.

3. Because life stages of delta smelt have different swimming motility, it is difficult to adequately use and subsequently compare the results of Particle Tracking modeling to what might actually occur to delta smelt in the Delta.

C. *Science needs for improved EWA implementation and evaluation:*

1. Acquire a better understanding of how the Particle Tracking model relates to actual Delta hydrology, and then to delta smelt movement and distribution.

2. Acquire a better understanding of how delta smelt are affected by the adverse impacts of the south Delta barriers and the entrainment that likely occurs through the un-screened agricultural diversions in the Delta. Determine the degree of modification required (flows, exports, barrier operations, etc.) in various modeling efforts to better protect delta smelt.

3. Develop fish monitoring that evaluates Delta barrier conditions in order to reduce uncertainty associated with potential impacts to fish from barrier operations.

4. Evaluate the impacts of predators and the construction of shallow-water habitat on delta smelt in the south Delta.

5. Evaluate potential ecosystem benefits and subsequent population benefits of EWA implementation using monitoring data and other information.

6. Develop better coordination of CVP and SWP operations with the installation of the Head of Old River Barrier and with salmon and delta smelt occurrence in the south Delta.

7. Define “Zone of Influence” and “Zone of Entrainment” and better incorporate these definitions into Particle Tracking modeling studies and EWA usage.

8. Use past years’ data and modeling results to relate trends to present year’s efforts.

9. Periodically review the Delta Native Fishes Recovery Plan to ensure that actions taken

move the target species toward recovery.

10. Determine how much EWA water would likely be needed to afford the desired level of protection for delta smelt in each year type and develop adequate EWA "place-holders" in each month from January through June (July and August as required).

D. *Proposed changes in the methods of implementing the EWA:*

1. Develop a comprehensive set of performance criteria to measure the effectiveness of using EWA water.

2. Continue to evaluate the content of *Fish Action* documents to assure their adequacy, and make modifications as needed.

3. Evaluate the DAT and Delta Smelt Work Group conference calls and note preparation process and modify as needed to improve efficiency and facilitate management-level review of DAT and Work Group recommendations.

4. When evaluating EWA and concurrent (b)(2) fish actions, develop mechanisms for coordination and evaluation of the underlying science.

5. Evaluate current fish sampling efforts and, if needed, establish additional fish sampling stations and efforts to improve the monitoring of fish distribution and relative abundance in the Delta.

6. Develop strategies that guide decision-making so as to consider the needs of all target species when EWA asset limitations come into play. Develop criteria for the identification of circumstances under which Tier 3 assets may be needed and establish a procedure for activating Tier 3 when any of the criteria are met.

7. Hold scientific workshops on specific topics relevant to EWA implementation in water year 2003. Workshops on conceptual models for delta smelt should continue.

8. Prioritize and implement key scientific studies important to EWA in water year 2003 based on above list of EWA science needs or recommendations from the EWA Science Review Panel.

Literature Cited

U.S. Fish and Wildlife Service 1993. Endangered and threatened wildlife and plants; Determination of threatened status for the delta smelt. March 5, 1993. Fed. Reg. 58(42):12854-12864

U.S. Fish and Wildlife Service 1995. Formal consultation and conference on effects of long-term operation of the Central Valley Project and State Water Project on the threatened delta smelt, delta smelt habitat, and proposed threatened Sacramento splittail. March 6, 1995. Memorandum Number 1-1-94-F-70

Nobriga, M., Z. Hymanson, K. Fleming and C. Ruhl. 2001. Spring 2000 delta smelt salvage and delta hydrodynamics and an introduction to the delta smelt decision tree. IEP Newsletter Vol. 14(2), Spring 2001

Table 1. Salvage of delta smelt at State and Federal export facilities for water year 2002.

Month	Salvage*	Red Light**
December	1,129	8,052
January	5,231	13,354
February	280	10,910
March	225	5,368
April	372	12,345
May	47,325	55,277
June	11,926	47,245

* source: CDFG fish salvage FTP site, www.delta.dfg.ca.gov/data/salvage

** for a below-normal year; source: USFWS 1995 Biological Opinion on the Long-Term Operation of the Central Valley Project (CVP) and the State Water Project (SWP)

Table 2. Summary of EWA expenditures for Water Years 2001 and 2002, in acre-feet.

Month	WY 2001	Benefit	WY 2002	Benefit
October			5,000	Salmonids
November			15,000	Salmonids
January	69,000	Salmonids	66,000	Salmon/Smelt
February	91,000	Salmonids/Smelt		
March	65,000	Salmonids/Smelt		

Month	WY 2001	Benefit	WY 2002	Benefit
April	35,000	Salmonids/Smelt	28,000	Salmonids/Smelt
May	42,000	Salmonids/Smelt	149,000	Salmonids/Smelt
June	9,000	Salmonids/Smelt	5,000	Salmonids/Smelt
Total	311,000		268,000	

source: EWA *Fish Action* summaries for water years 2001 and 2002

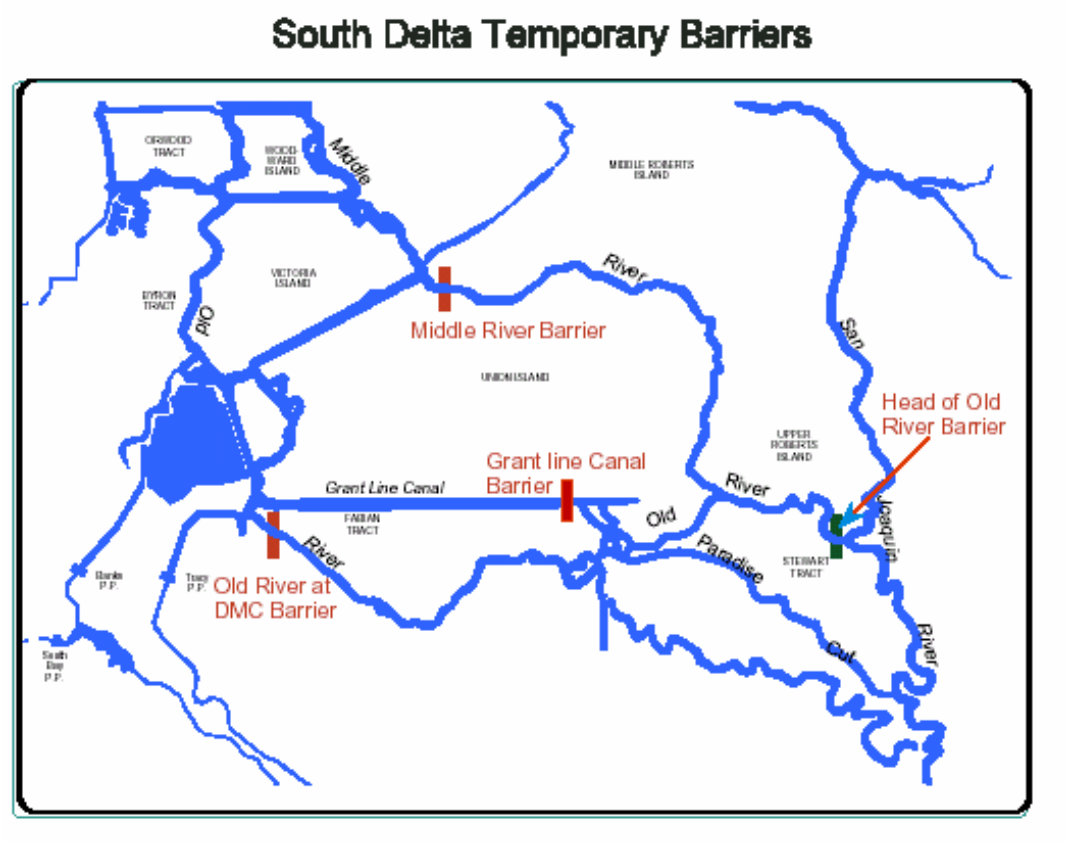

Figure 1. Locations of the South Delta Temporary Barriers (graphic provided by DWR).

Figure 2. Delta smelt salvage at the Federal and State export facilities, for January 2002.

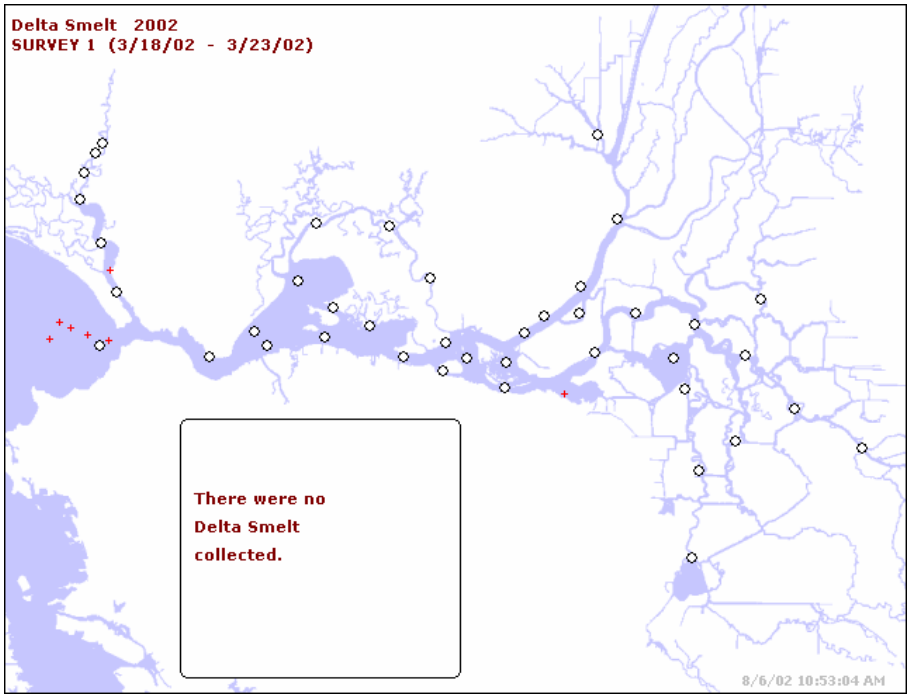

Figure 3. Results of 20 millimeter Survey Number 1 for Delta Smelt.

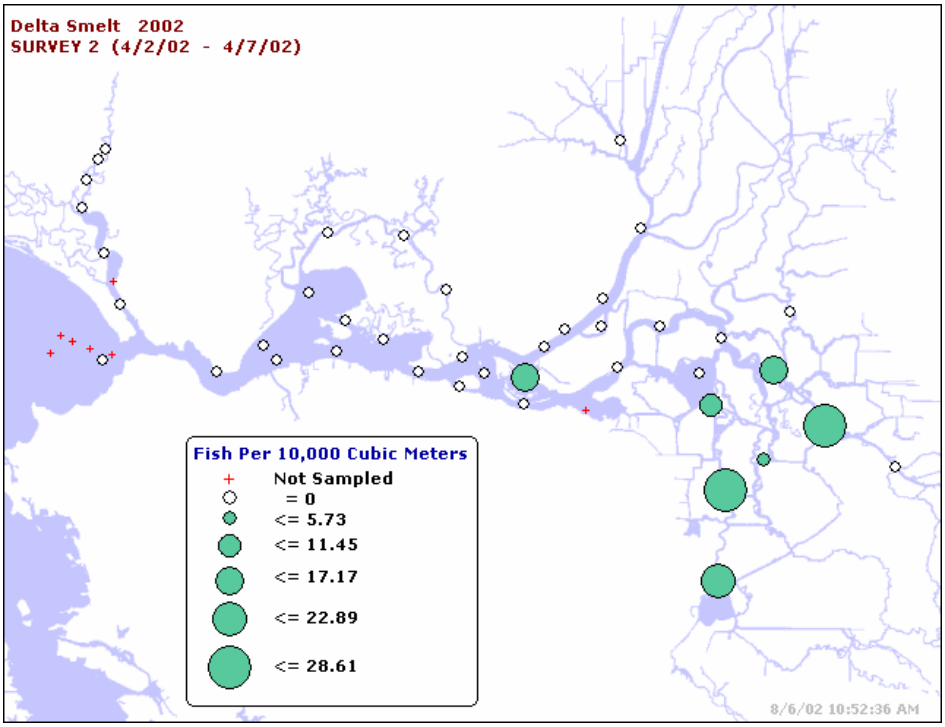

Figure 4. Results of 20 millimeter Survey Number 2 for Delta Smelt.

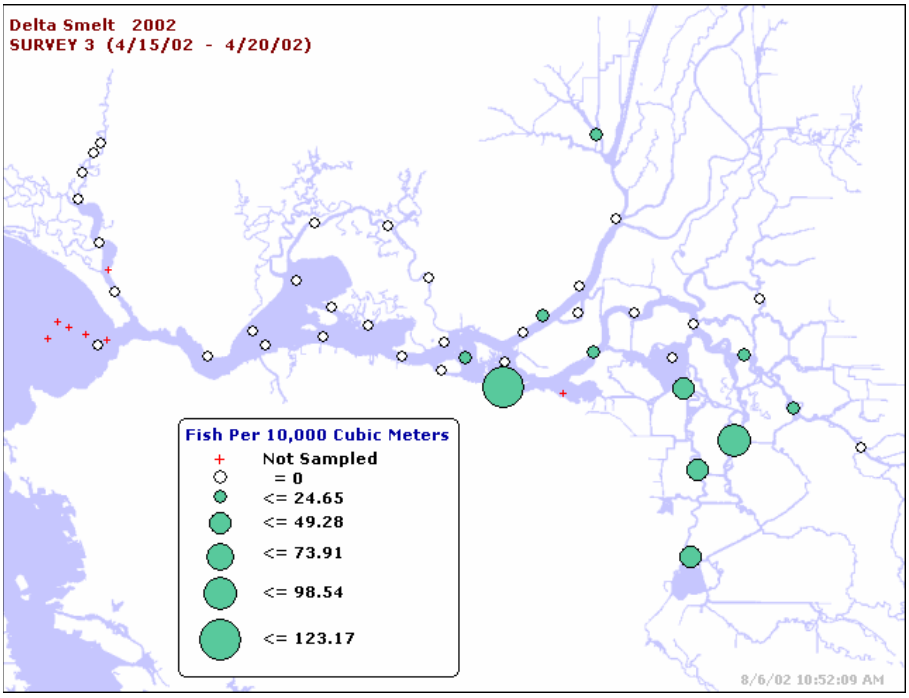

Figure 5. Results of 20 millimeter Survey Number 3 for Delta Smelt.

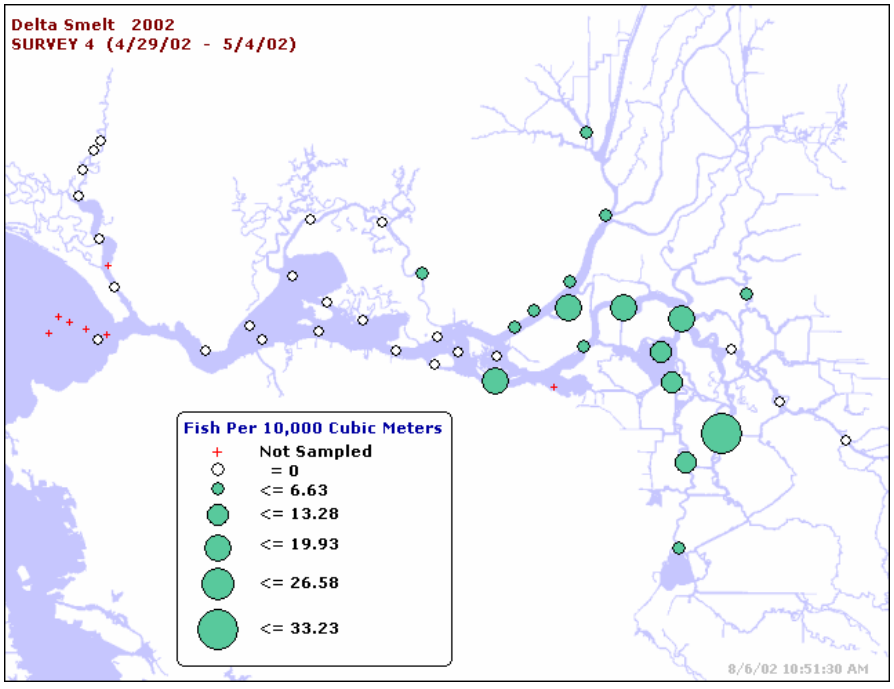

Figure 6. Results of 20 millimeter Survey Number 4 for Delta Smelt.

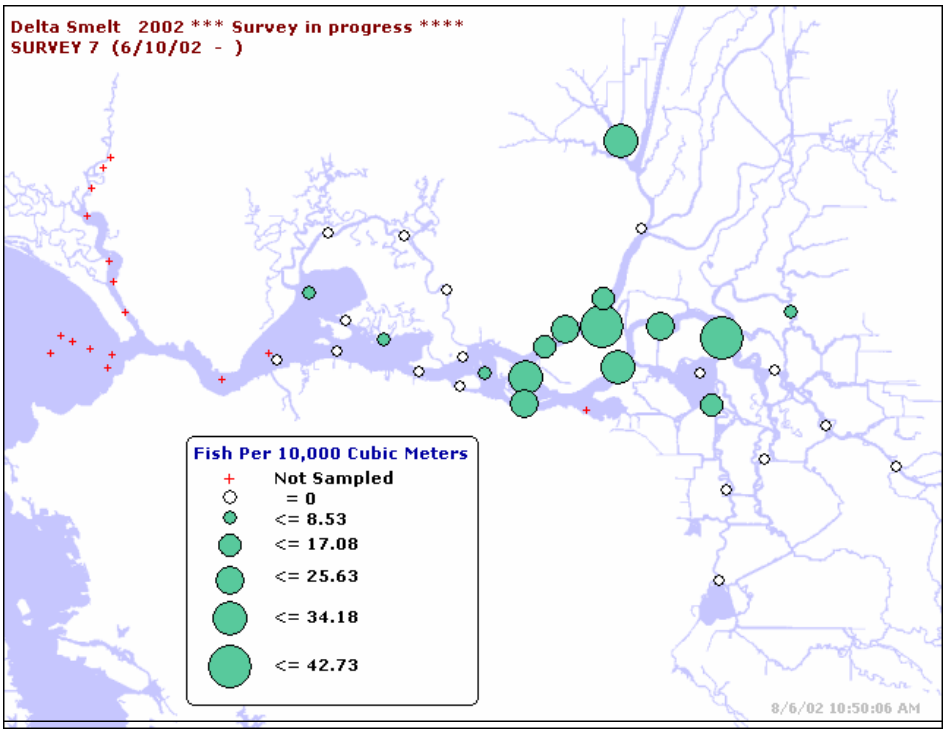

Figure 7. Results of 20 millimeter Survey Number 5 for Delta Smelt.

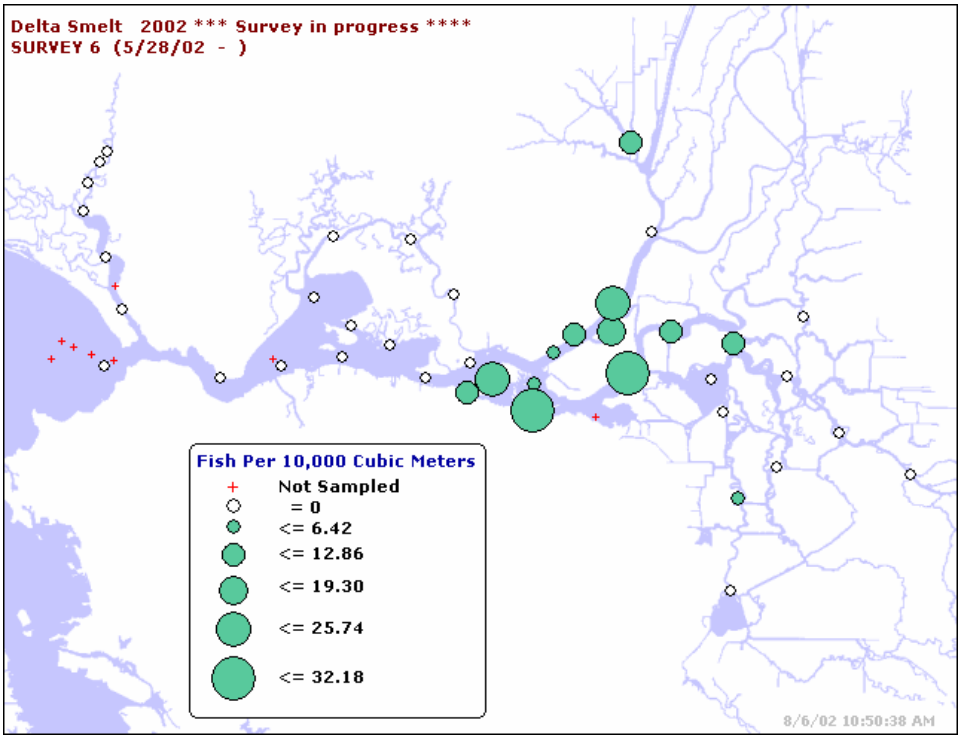

Figure 8. Results of 20 millimeter Survey Number 6 for Delta Smelt.

Figure 9. Results of 20 millimeter Survey Number 7 for Delta Smelt.

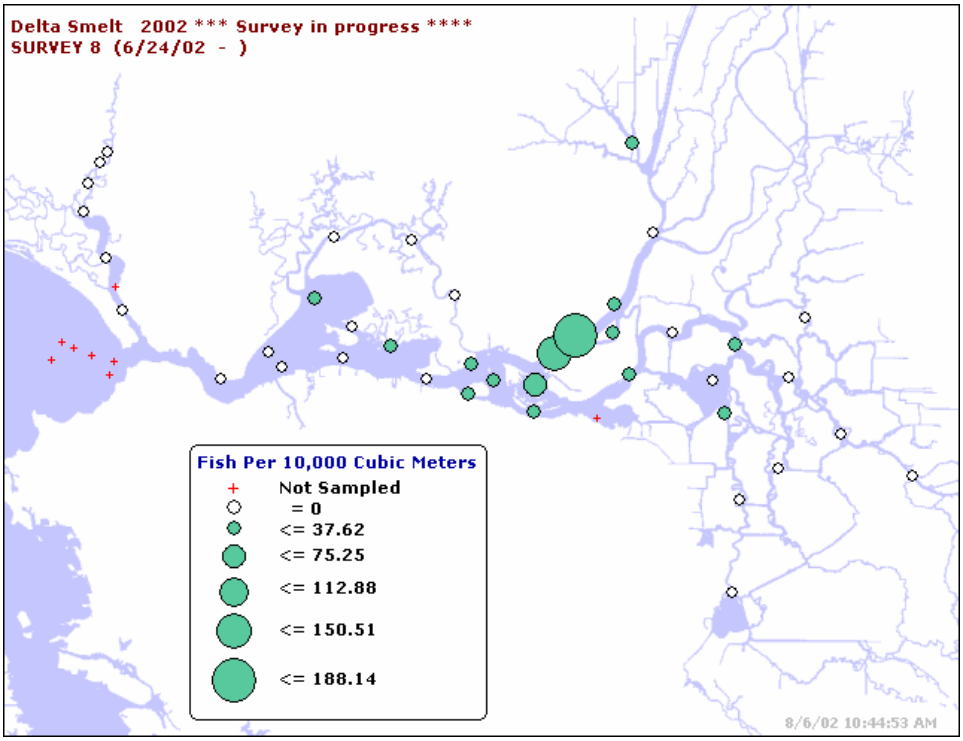

Figure 10. Results of 20 millimeter Survey Number 8 for Delta Smelt.

Figure 11. Delta smelt salvage at the Federal and State export facilities, for May 2002.

Figure 12. Delta smelt salvage at the Federal and State export facilities, for June 2002.

Attachment

CONTRIBUTED PAPERS

SPRING 2000 DELTA SMELT SALVAGE AND DELTA HYDRODYNAMICS AND AN INTRODUCTION TO THE DELTA SMELT WORKING GROUP'S DECISION TREE

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Introduction and Background

The delta smelt (*Hypomesus transpacificus*) is listed as a threatened species under both the Federal Endangered Species Act (FESA) and the California Endangered Species Act. Through formal consultation under Section 7 of the FESA, USBR and DWR received a biological opinion from USFWS, which allows for the incidental take of delta smelt arising through operation of the Central Valley Project (CVP) and the State Water Project (SWP). The incidental take of delta smelt is estimated as part of CVP and SWP fish salvage operations. Salvage levels of young delta smelt have exceeded incidental take levels every spring and summer since 1996, except in the very high spring outflow year of 1998 (Table 1). These high salvage levels have resulted in changes to project operations, often leading to the curtailment of water exports.

Nobriga and others (2000) reviewed data on delta smelt distribution, recruitment patterns and salvage, as well as Delta hydrodynamics during the moderately wet springs of 1996 and 1999 to provide hypotheses about why springtime delta smelt salvage has been consistently high. Based on their review, Nobriga and others (2000) suggested the following:

- Moderate winter-spring flows in the San Joaquin River may result in attraction of spawning delta smelt into the central Delta.
- Maintenance of moderate central Delta flows during the Vernalis Adaptive Management Plan (VAMP) provides good larval rearing habitat within the Delta[1].

Table 1 Estimated combined CVP and SWP salvage of delta smelt from April through August, 1994 through 2000[a]

Year	Water year type[b]	Month				
		Apr	May	Jun	Jul	Aug
1994	B	945	31,901	8,801	1,509	0
1995	A	24	0	0	0	0
1996	A	111	**30,099**	9,465	148	0
1997	A	1,159	**32,828**	7,876	228	0
1998	A	48	4	66	124	0
1999	A	410	**58,943**	**73,368**	**20,272**	48
2000	A	1,746	**49,401**	**49,124**	1,513	6

[a] Total salvage numbers that exceeded the red light take levels are shown in bold type. Red light take levels for above normal water years (1995–2000) are April = 2,378, May = 9,769, June = 10,709, July = 9,617, and August = 4,818. Red light take levels for below normal water years (1994) are April = 12,345, May = 55,277, June = 47,245, July = 35,550, and August = 25,889.

[b] B = below normal, A = above normal.

Although delta smelt salvage was very high in both 1996 and 1999, total salvage was much higher in 1999. Nobriga and others (2000) suggested two factors were primarily responsible for the higher salvage in 1999.

- The apparent recruitment of delta smelt, as inferred from the DFG 20-mm Survey, occurred for a longer period in 1999 than in 1996.
- Net flows in Old and Middle rivers at Bacon Island during the 1999 VAMP remained near zero much of the time, whereas they were typically positive during 1996. Presumably, positive net central Delta flows during the 1996 VAMP helped move larval delta smelt downstream away from the zone of influence of the south Delta facilities before they reached a size they could be observed in the salvage operations when exports were ramped up following the VAMP.

Based on data from 1996 and 1999, and forecasts of central Delta flows for spring 2000, Nobriga and others (2000) predicted delta smelt salvage would exceed the red light levels in 2000. As predicted, delta smelt salvage did

1. See also "Vernalis Adaptive Management Plan 2000 Salmon Smolt Survival Investigations" on page 47.

exceed red light levels in May and June 2000. In this article we review data on delta smelt salvage in conjunction with hydrodynamic data for spring and early summer 2000 to provide additional evidence that high spring salvage may result from VAMP operations. We also provide an overview of the Decision Tree Process used by the Delta Smelt Workgroup to help determine when changes to water project operations may be warranted.

Overview of Hydrodynamics Methods

The USGS collected tidal flow data on a 15-minute interval at Old and Middle rivers using ultrasonic velocity meters (UVM) (Oltmann 1998). These data were tidally averaged to provide net flow at each location. The net flow at Old and Middle rivers will be referred to as central Delta flows throughout this article.

Vernalis Flow and Delta Smelt

Nobriga and others (2000) hypothesized the occurrence of intermediate flows on the San Joaquin River in late winter 1996 and 1999 provided attractive conditions for adult delta smelt moving upstream to spawn. During winter and spring 2000, San Joaquin River flow at Vernalis was similar in timing and magnitude to the other recent moderately wet years reviewed by Nobriga and others (2000) (Figure 1). However, it is unknown what proportion of adult delta smelt spawned in any particular part of the Delta during any of these years. DFG is conducting a study designed to better characterize delta smelt spawning habitats. The results of this study may be very useful to forecasting high salvage events.

Since 1996, additional reservoir releases from the San Joaquin system have been provided for a 30-day period from mid-April to mid-May as part of the VAMP. This "pulse flow" was designed to provide transport flows for chinook salmon emigrating from the San Joaquin basin. The pulse flow is also thought to provide beneficial transport and habitat enhancement flows for delta smelt larvae spawned in the central and south Delta. However, by improving in-Delta habitat conditions and reducing net negative flows, VAMP may be responsible for the consistent exceedance of red light take levels in late spring and early summer. In years before the implementation of the VAMP, central Delta flows were typically negative throughout the spring. Presumably delta smelt spawned in the south Delta would have been entrained as larvae before they grew large enough to be salvaged at the facilities (see below). With the implementation of the VAMP pulse flow period, there is a window of time each spring during which central Delta flows range from only slightly negative to slightly positive. Nobriga and others (2000) hypothesized that the pulse flow allows delta smelt spawned in the central and south Delta to rear and grow large enough to be observed in the salvage (see below) once the pulse flow ends.

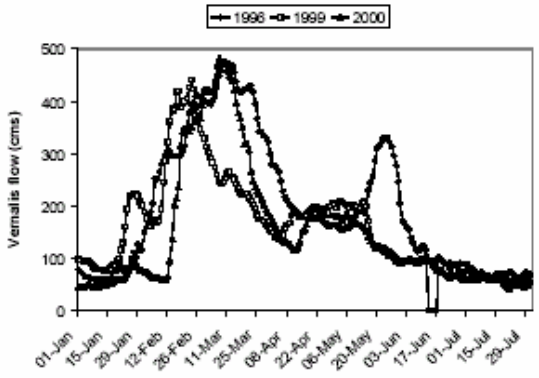

Figure 1 San Joaquin River flow at Vernalis (cubic meters per second) from January through July for moderately wet years 1996, 1999, and 2000

Overview of Salvage Patterns and Delta Hydrodynamics

Salvage of young delta smelt at the SWP and CVP Delta fish facilities begins to be quantified each spring when the smelt reach a length of about 25 mm. In terms of total delta smelt salvaged, 2000 was similar to recent years with high salvage occurring in May and June (Table 1). As in previous years (Nobriga and others 2000) delta smelt salvage began to increase, particularly at the SWP, at the end of the VAMP, about May 20 (Figure 2). Interestingly, the salvage increase was associated with only a very slight change in central Delta flows (Figure 3), suggesting the increase was triggered by smelt residing near the facilities. In response to the abrupt increase in delta smelt salvage, SWP exports were cut back and CVP exports were increased for a few days beginning about May 25 (see article by Le on page 9 for details about operations changes). Salvage densities decreased in response to this change in operations, but increased again when the SWP increased exports beginning about May 27. Despite a noticeable decrease in salvage density throughout June, the total number of delta smelt salvaged

during June was about the same as in May (Table 1) due to the larger volume of water exported in June (Figure 4).

In conclusion, San Joaquin River flows during winter and early spring 2000 were similar to other years hypothesized by Nobriga and others (2000) to attract spawning delta smelt into the central Delta. Delta smelt salvage quickly exceeded red light levels following the VAMP in 2000 as it has in most recent years. This lends additional support to the hypothesis that the VAMP results in suitable larval rearing conditions within the central and south Delta, and therefore high salvage when CVP and SWP exports ramp up after VAMP. This should not be interpreted as meaning entrainment losses of delta smelt are higher now than they were historically. We believe the difference is that some of the fish that would historically have been "silently" entrained as larvae, now grow to a detectable size during the VAMP period and are therefore counted in salvage during late May and June.

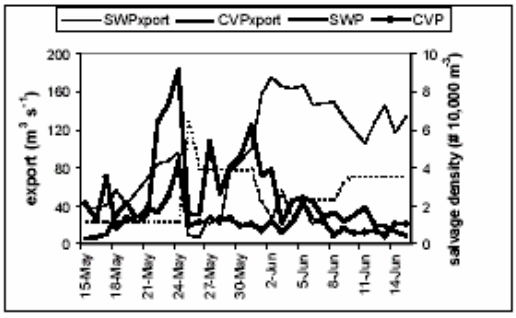

Figure 2 Daily CVP and SWP export rates and delta smelt salvage density for the 30-day period following the conclusion of the VAMP pulse flow in 2000

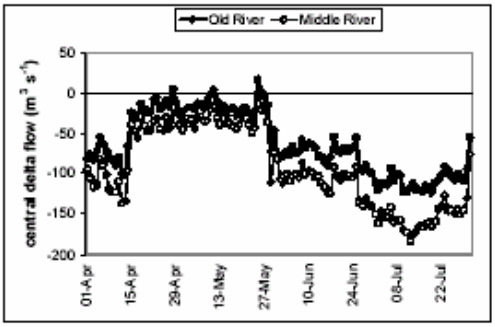

Figure 3 Tidally averaged (net) flow in Old and Middle rivers at Bacon Island from April through July as measured by ADCPs operated by USGS

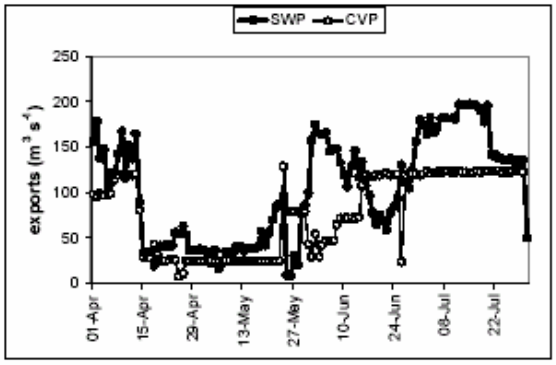

Figure 4 CVP and SWP daily export rates from April through July 2000

Delta Smelt Working Group Decision Tree Process

The Delta Smelt Working Group is a product of the 1995 delta smelt biological opinion. As defined in the opinion, the group's purpose is "…to resolve biological and technical issues raised by this opinion and to develop recommendations for consideration by the management group." Participants include agency personnel from USFWS, NMFS, DFG, USBR, EPA, DWR and SWRCB. The Delta Smelt Decision Tree (Table 2) is the written description of the types of information, questions, and thought processes the working group uses to determine if recommendations for operational changes are warranted. The decision tree is not intended to add any new requirements or criteria, but rather it is intended to inform other interested parties of the decision processes presently in use.

Reference

Oltmann RN. 19983 Measured flow and tracer-dye data showing anthropogenic effects on the hydrodynamics of south Sacramento-San Joaquin Delta, California, spring 1996 and 1997. USGS Open-File Report 98–285. Sacramento (CA): U.S. Geological Survey. 16 p.

Table 2 The Delta Smelt Decision Tree

Life stage	Adults
Timing	Pre-VAMP (February 1 through April 15)
Concerns	1) High relative densities of adults in the south Delta are a concern due to the potential for increase entrainment at the SWP and CVP.
	2) High relative densities of delta smelt in the south Delta also suggest spawning may occur in the south Delta, increasing the chances for exceeding the red light level[a] of incidental take in the late spring and early summer.
Data of interest	Before pre-VAMP, consider fall midwater trawl indices
	Spring midwater trawl
	Salvage
	Beach seine
	Chipps Island trawl
	Hydrology (wet or dry year; placement of X2)
	Water quality conditions and water temperature
	Condition of the fish
Assessment of conditions	Adult distribution in Delta and downstream of the Delta
	Salvage levels/densities, yellow light
	Potential high numbers in juvenile salvage if high numbers of adults are concentrated in the south Delta
Tools for change	Reduction in exports, either concurrently at both facilities or at the facility that is salvaging the most fish
Biological questions using the available data	1) Is the adult distribution broad or not?
	2) Is salvage elevated or not?
	3) Is previous FMWT index high or low?
	4) Are water quality conditions (e.g. water temperatures) conducive to spawning?
	5) Are fish ripe for spawning? (Both of above may help determine if there will be a protracted spawn.)
Questions concerning operations	1) Is there a need to reduce exports at either or both facilities based on either the distribution of adults and/or an increase in the salvage of adult delta smelt?
	2) Is it likely to be a difficult spring or summer? That is, do we expect high levels of delta smelt salvage in the spring or summer?
Assessment of concern	I. If the stated recovery criteria index is lower than 239, then concern is high.
	II. If distribution information shows adults delta smelt are concentrated in the south and central Delta, then concern is high.
	III. If the observed or predicted salvage of adults increases sharply, then concern is high.
	IV. If fish at the salvage facilities are on the verge of spawning and temperatures are conducive to spawning, then concern is high.
Recommendations	A) If concern is high and salvage increases abruptly, then recommendations for action is likely.
	B) If the observed or predicted salvage is at or approaching the red light or at the yellow light, then a recommendation for action is likely.
	C) If assessments II and I are true, then we expect a difficult spring or summer (June and July).
Life stage	**Larvae**
Timing	VAMP (April 15 through May 15)
Concerns	High numbers of larvae in the south Delta will likely result in higher numbers of fish rearing to juvenile stages and higher levels of entrainment.
Data of interest	Light traps surveys
	20-mm survey[b]
	Water temperatures
	Salvage[c]
	Hydrology (wet or dry year; placement of X2)
Assessment of conditions	Spawning distribution
	Percent distribution

[a] Yellow light and red light as defined in the 1995 OCAP opinion.
[b] If fortnightly 20-mm survey is occurring and red light occurs, then effort will increase to weekly sampling.
[c] Salvage levels at this time will likely not reflect the number of delta smelt in the south Delta, since smelt begin to be counted at the salvage facilities at about 25 mm.
[d] The barriers shall be operated as stated in the USFWS biological opinion (1-1-96-F-53), April 26, 1996.
[e] Changes considered under "a" and "b" would aim to increase net positive flows in Old and Middle rivers downstream of the export facilities.

Table 2 The Delta Smelt Decision Tree (Continued)

Assessment of conditions (continued)	Timing: start and duration of spawning
	Implement model to predict future salvage (end of VAMP)
	Water quality conditions, water temperature
Tools for change	Change in San Joaquin River flows
	Change in export reductions (1–3 = net flow)
	Change in barrier operations
Biological questions using the available data	1) Is distribution of spawning broad or restricted?
	2) Is larval distribution broad or restricted?
	3) When does spawning start?
	4) Do we expect punctuated or protracted spawning?
	5) Do we expect SWP and CVP to reach red light salvage levels?
Questions concerning operations	Do we consider changing net flows in Old and Middle rivers?
Assessment of concern	I. If light trap results demonstrates that spawning has occurred in the south Delta, then concern is high
	II. If the 20-mm survey shows 50% of the delta smelt are in the zone of influence (e.g., east of the confluence), then concern is high.
	III. If abundance in the 20-mm survey is low relative to other years, then concern is high.
	IV. If substantial larval recruitment is expected to occur in the south and central Delta post-VAMP, then concern is high
Recommendation	If concern is high and salvage is at or approaching red light or at yellow light, then recommendations to improve net flow in Old and Middle Rivers are likely. (This recommendation applies during VAMP and post-VAMP, although the tool used will vary.)
Life stage	**Juveniles**
Timing	Post-VAMP (May 15 through July 1)
Concerns	High numbers of delta smelt juveniles in the south and central Delta will likely result in increased entrainment when export levels increase at the end of VAMP
Data of interest	20-mm survey[b]
	Salvage
	Summer townet
	Hydrology (wet or dry year; placement of X2)
	Export rates
Assessment of conditions	Percent of the distribution outside the zone of influence (e.g., east and west of the confluence)
	Salvage level (number)
	Salvage density
Tools for change	Change in exports
	Change in agricultural barrier operations[d]
	Removal of HORB[d]
	Position of cross-channel gates
	Flow changes in San Joaquin, Old, and Middle rivers
Biological questions using the available data	1) What is the relative distribution in and outside the zone of influence (e.g. upstream and downstream of the confluence)?
	2) Is abundance high?
	3) Is salvage at or approaching red light or at yellow light?
	4) Are fish migrating west from the Delta?
Questions concerning operations	1) Do we consider changing exports?[e]
	2) Do we consider changing agricultural barrier/HORB operations?[e]
	3) Do we consider changing the position of the cross channel gates after May 20?
Assessment of concern	I. If the 20-mm survey shows 50% of the delta smelt are in the zone of influence (e.g. east of the confluence), then concern is high.
	II. If abundance in the 20-mm survey is low, relative to other years, then concern is high.
Recommendation	If concern is high and salvage is at or near red light, then recommendation for action is likely.

[a] Yellow light and red light as defined in the 1995 OCAP opinion.
[b] If fortnightly 20-mm survey is occurring and red light occurs, then effort will increase to weekly sampling.
[c] Salvage levels at this time will likely not reflect the number of delta smelt in the south Delta, since smelt begin to be counted at the salvage facilities at about 25 mm.
[d] The barriers shall be operated as stated in the USFWS biological opinion (1-1-96-F-53), April 26, 1996.
[e] Changes considered under "a" and "b" would aim to increase net positive flows in Old and Middle rivers downstream of the export facilities.